

A decorative graphic on the left side of the slide, featuring a blue and yellow abstract shape at the bottom, a white grid pattern, and a blue sky with clouds and a white airplane flying across it.

Computer Modeling and Simulation of Aeronautical Communications Systems at MITRE/CAASD

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Introduction

- **The MITRE Corporation's Center for Advanced Aviation System Development (CAASD) has developed computer simulation models for some air/ground communications systems including:**
 - **Mode Select (S)**
 - **Very High Frequency (VHF) Digital Link (VDL) Mode 2**
 - **VDL Mode 3**
 - **Aeronautical Telecommunication Network (ATN)**

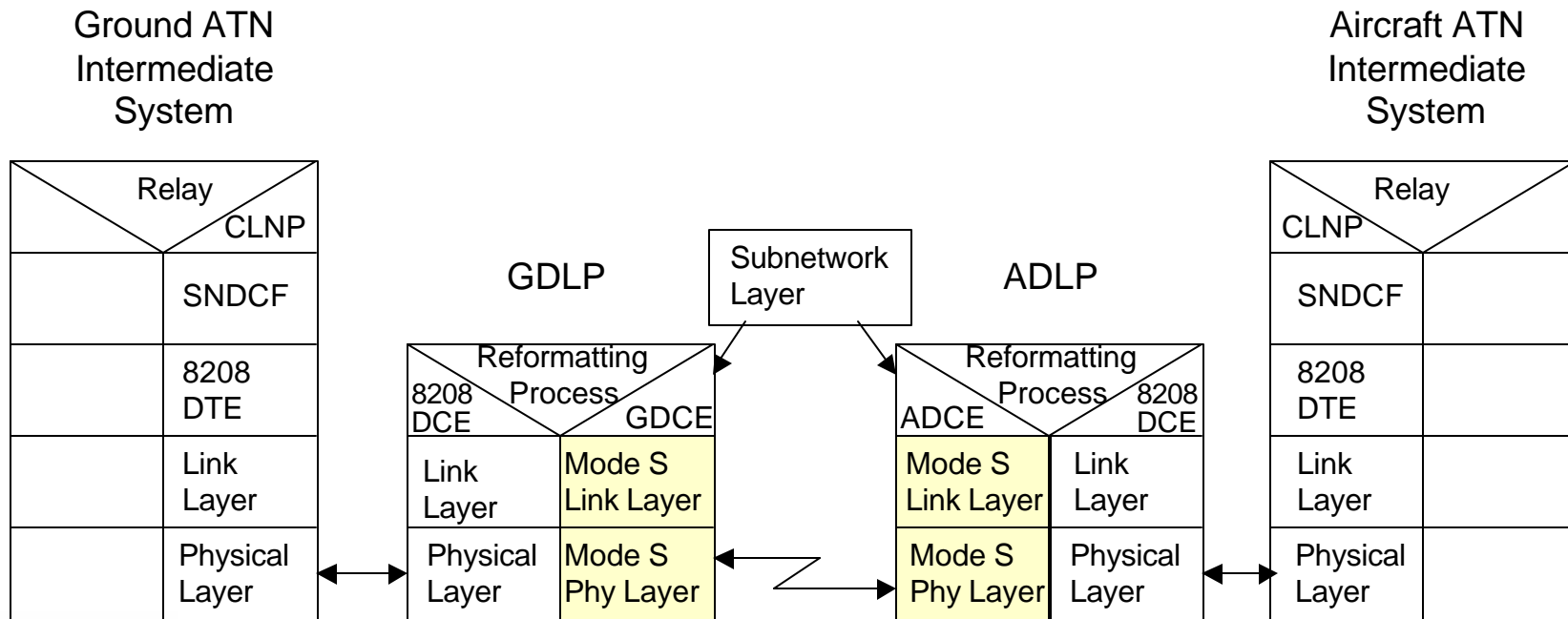
Introduction (Concluded)

- **These models have been used in:**
 - system development
 - standards validation
 - system performance evaluation
 - system performance improvement
- **Some models have been shared with the industry**
- **Through an FAA Cooperative Research and Development Agreement, have cooperated with ARINC on VDL Mode 2 modeling and simulation**

Mode S Subnetwork

Physical Layer	
Frequency	1030 MHz uplink, 1090 MHz downlink
Modulation	Differential Phase Shift Keying (DPSK) uplink, Pulse Position Modulation (PPM) downlink
Bit Rate	4 Mbps uplink and 1 Mbps downlink burst rate
Link Layer	
MAC	Polling by the ground interrogator
Data Link Control	Discretely addressed frames that require acknowledgment and broadcast frames
Subnetwork Layer	
ATN Interface	ISO 8208
Mode S subnetwork layer	ISO 8208 like protocol (GDCE and ADCE)

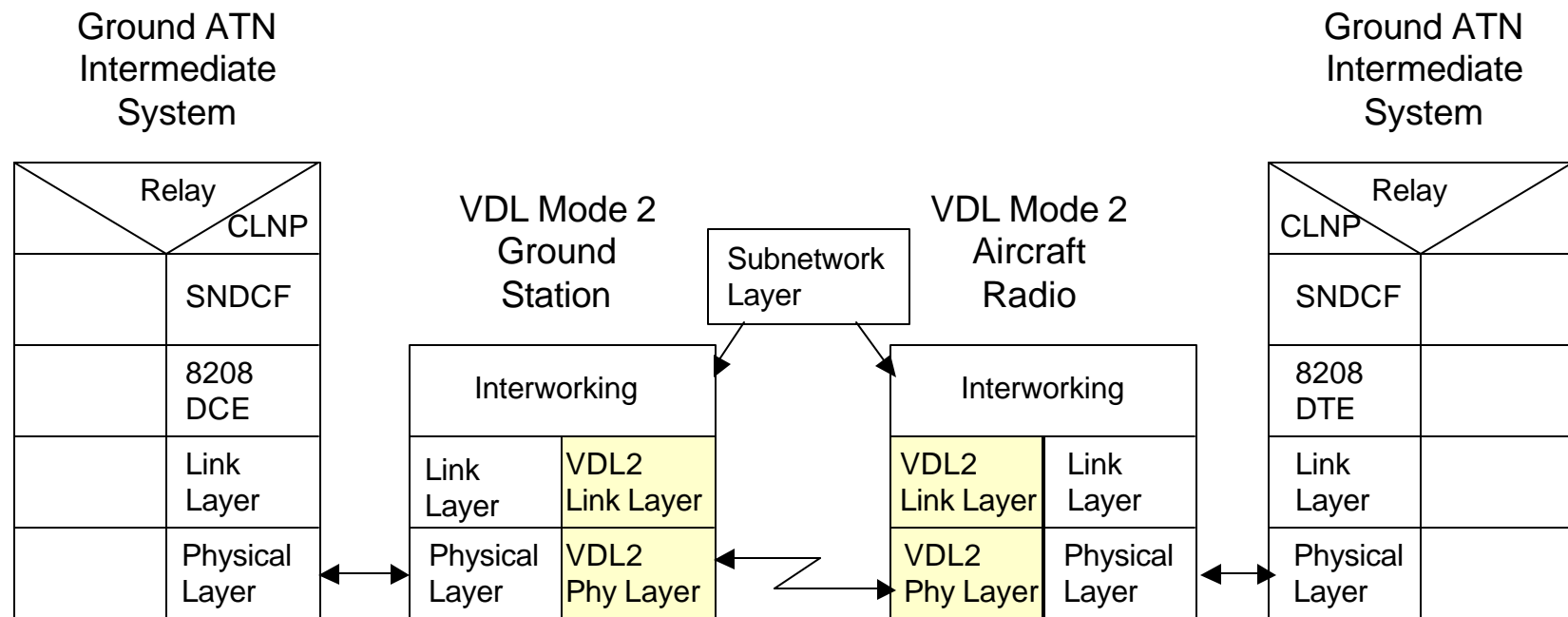
Mode S Subnetwork (Concluded)



VDL Mode 2 Subnetwork

Physical Layer	
Frequency	117.975-137 MHz with independent 25 kHz channels
Modulation	Differential 8-ary Phase Shift Keying (D8PSK)
Bit Rate	31.5 kbps burst rate
Link Layer	
MAC	Carrier Sense Multiple Access (CSMA)
Data Link Control	Aviation VHF Link Control (AVLC) Discretely addressed frames that require acknowledgment (similar to HDLC) and broadcast frames
VME	Establishes and maintains link layer connections
Subnetwork Layer	
ATN Interface	ISO 8208
VDL Mode 2 subnetwork layer	None

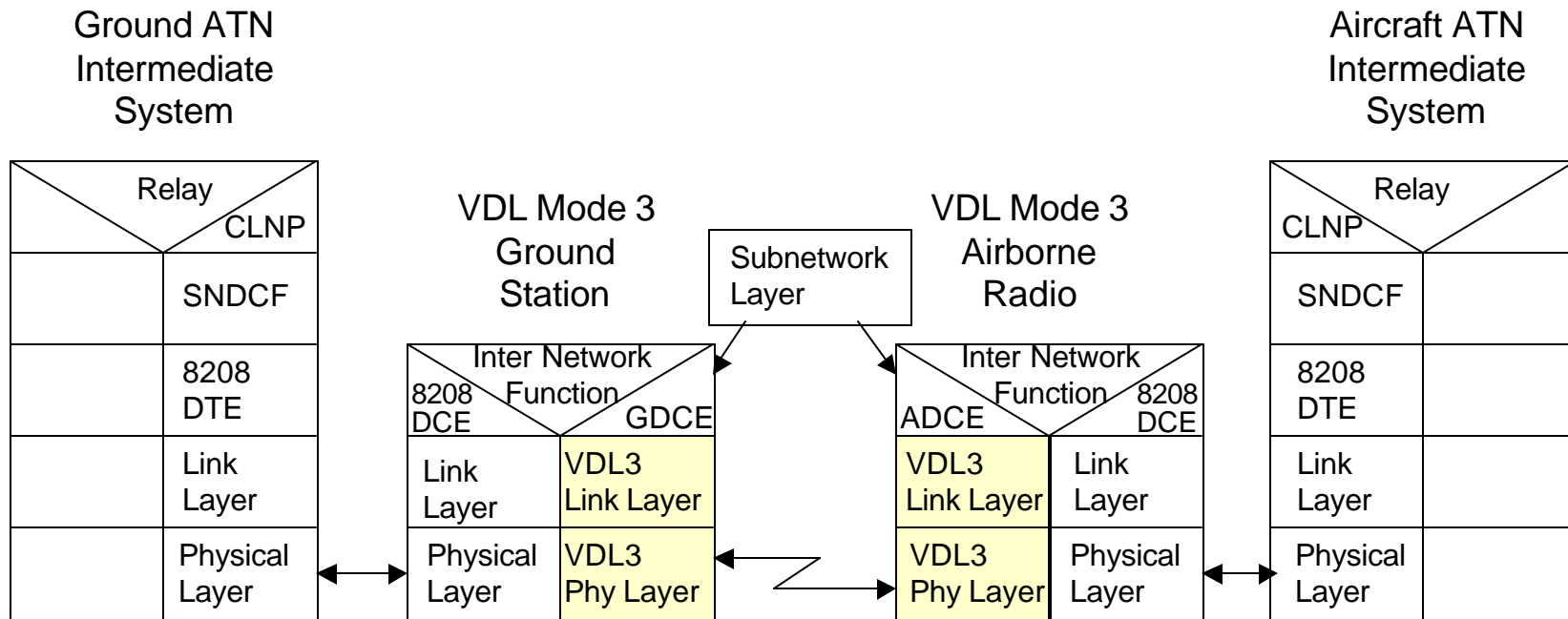
VDL Mode 2 Subnetwork (Concluded)



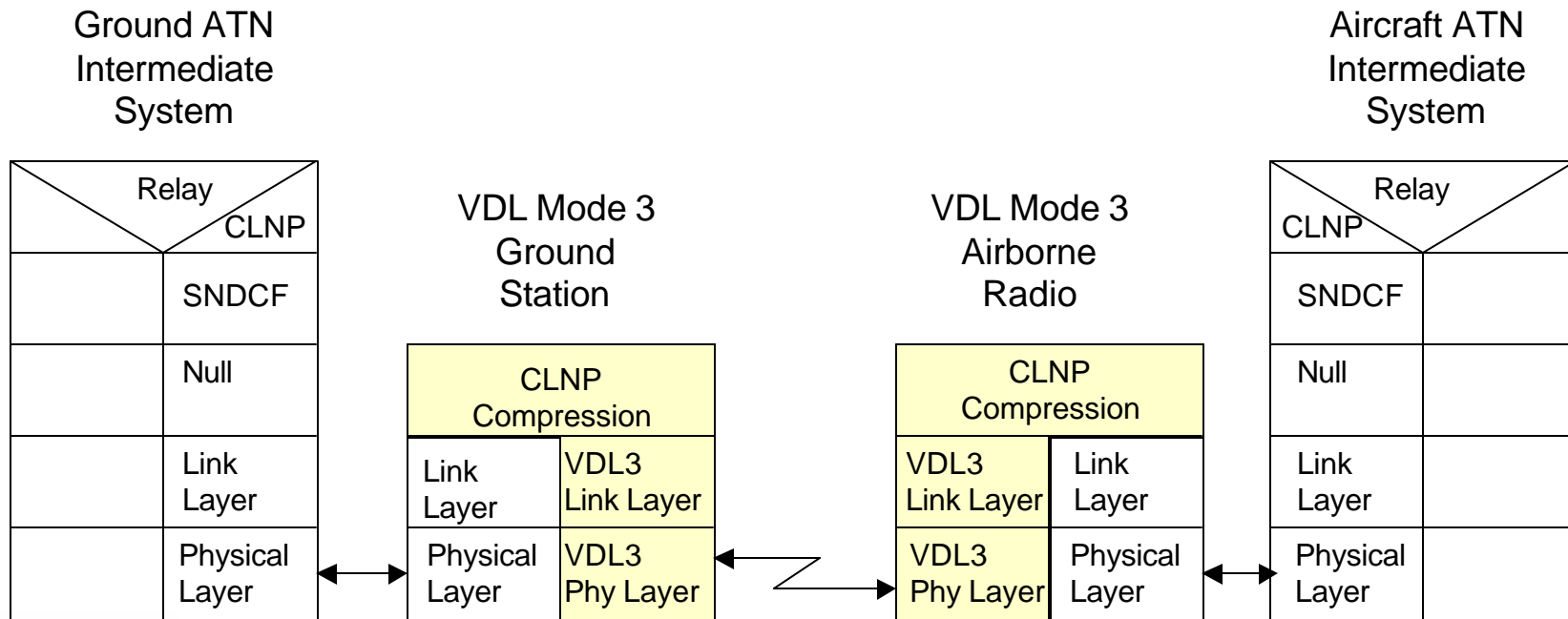
VDL Mode 3 Subnetwork

Physical Layer	
Frequency	117.975-137 MHz with independent 25 kHz channels
Modulation	Differential 8-ary Phase Shift Keying (D8PSK)
Bit Rate	31.5 kbps burst rate
Link Layer	
MAC	Time Division Multiple Access (TDMA)
Data Link Control	Discretely addressed frames that require acknowledgment (stop-and-wait protocol) and broadcast frames
LME	Establishes and maintains link layer connections
Subnetwork Layer	
ATN Interface	ISO 8208 or CLNP compression
VDL Mode 3 subnetwork layer	Optimized ISO 8208 or none

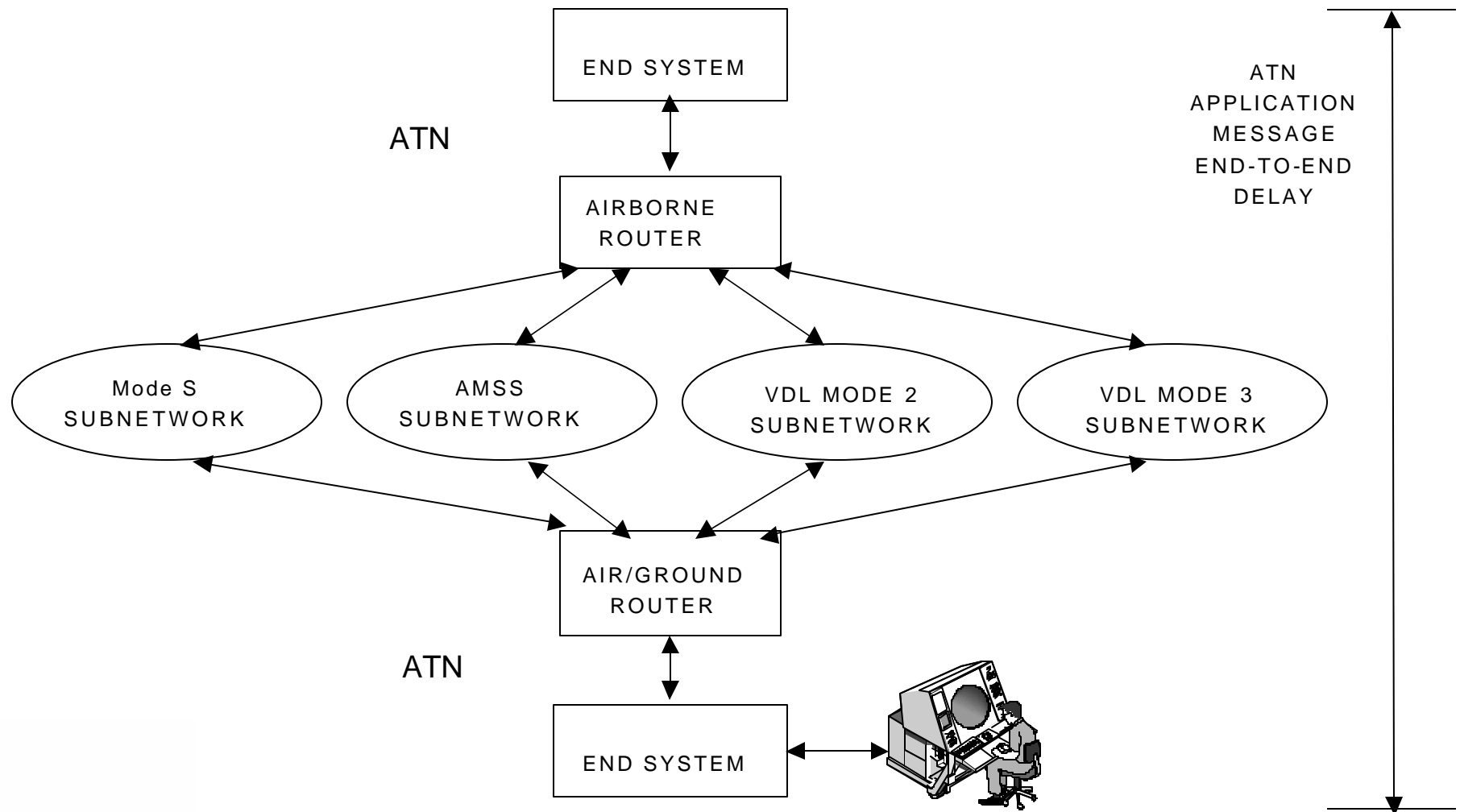
VDL Mode 3 Subnetwork (Continued)



VDL Mode 3 Subnetwork (Concluded)



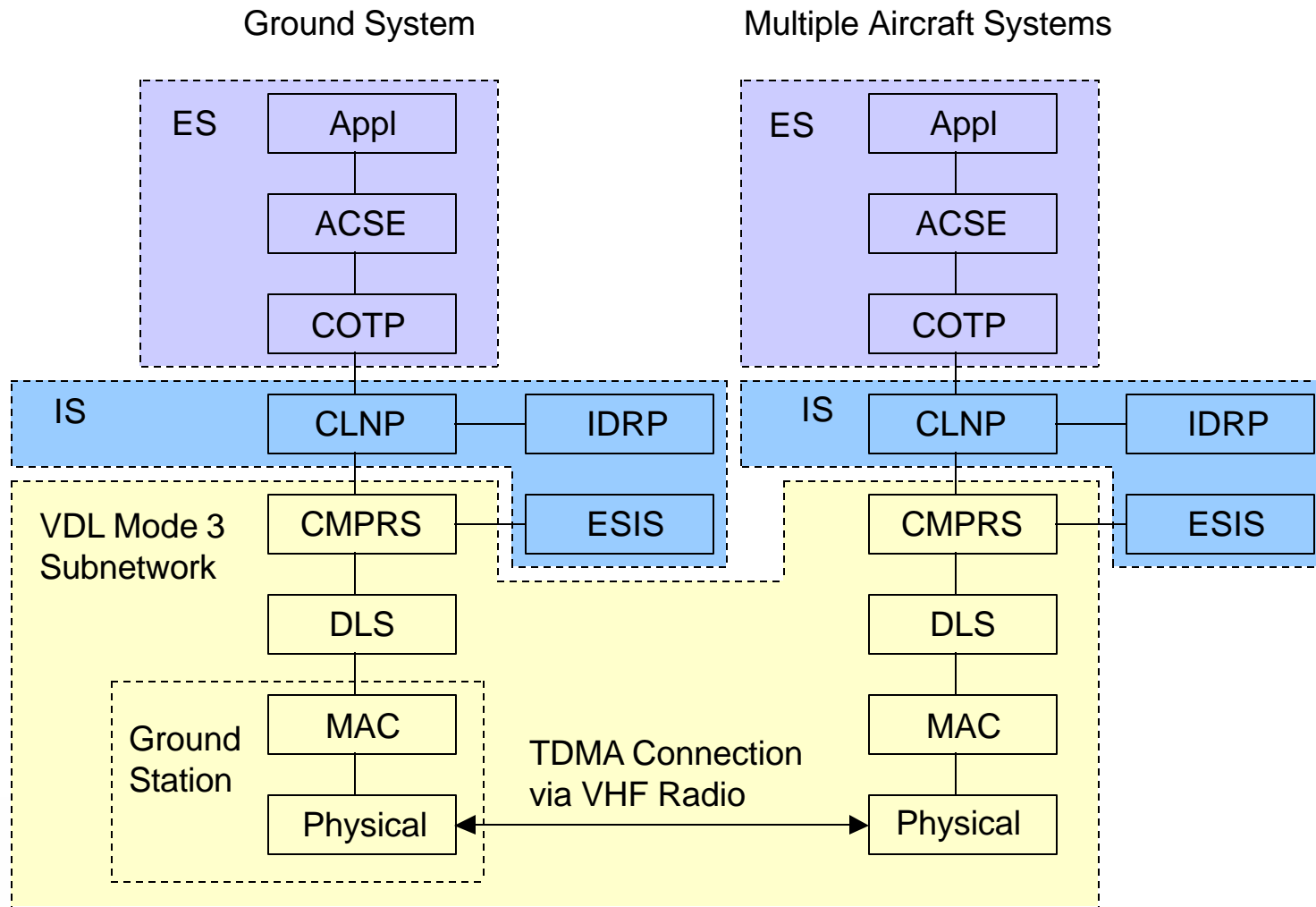
ATN



Summary of MITRE/CAASD Implemented Models and Functions

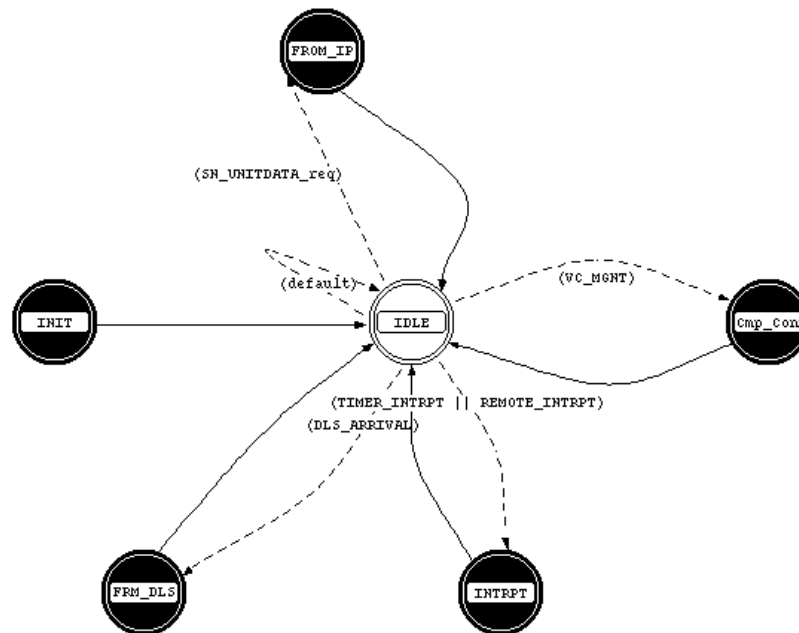
Aeronautical Communications System Models	Implemented Functions
ATN	CLNP (ISO 8473)
	COTP (ISO 8073)
	ES-IS (ISO 9542)
	IDRP (ISO 10747)
Mode S Subnetwork	Physical layer (4 Mbps uplink and 1 Mbps downlink)
	MAC
	Data link layer
Mode S Subnetwork/ATN	Mode S subnetwork functions and ATN functions
VDL Mode 2 Subnetwork	Physical layer (D8PSK modulation, 31.5 kbps)
	MAC (CSMA)
VDL Mode 3 Subnetwork	Physical layer (D8PSK modulation, 31.5 kbps)
	MAC (2V2D, 3T, 1V3D system configurations)
	DLS (Stop-and-wait and broadcast)
	LME (XID commands)
	Subnetwork layer (CLNP compression)
Integrated VDL Mode 3 Subnetwork 2V2D System Configuration/ATN	VDL Mode 3 subnetwork functions including 2V2D system configuration and ATN functions
Integrated VDL Mode 3 Subnetwork 1V3D System Configuration/ATN	VDL Mode 3 subnetwork functions including 1V3D system configuration and ATN functions

An Integrated VDL Mode 3/ATN Model



Simulation Tool

- **OPNET Modeler by OPNET Technologies, Inc.**
 - An object-oriented discrete event simulation tool
 - Protocols modeled by state machines

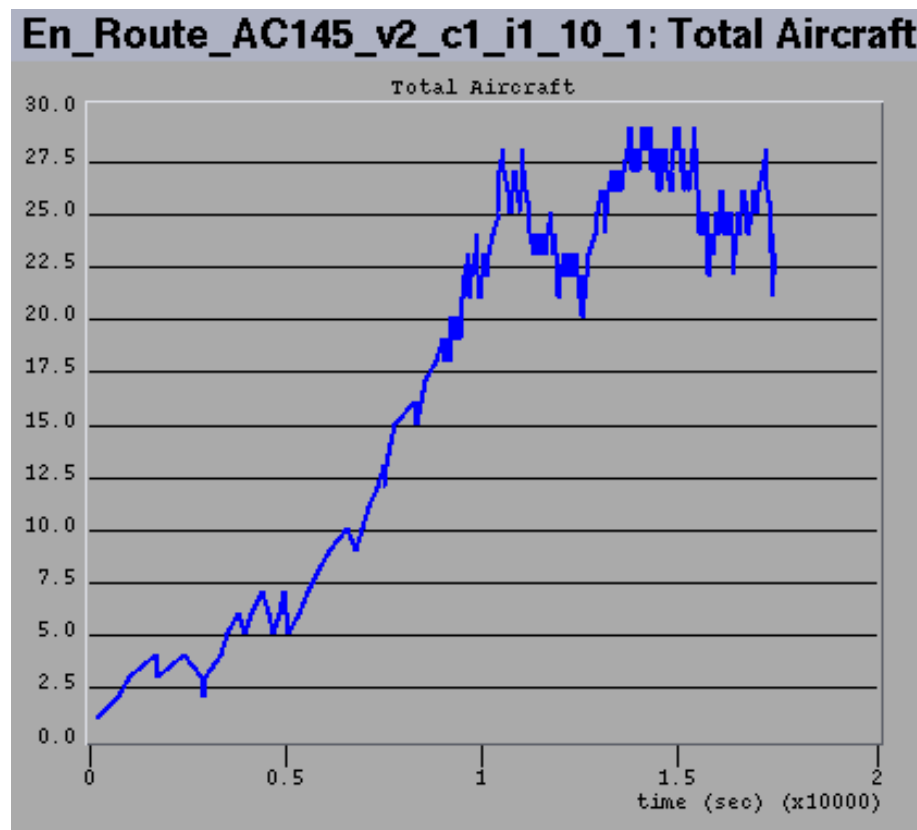


Simulation

- **Performed simulations of aeronautical communications systems models under various number of aircraft and application traffic loadings to collect statistics on performance metrics**
- **Results have been presented in various forums including OPNETWork and Digital Avionics Systems Conference (DASC). References are included in the paper.**

Number of Aircraft

- Models with different average number of aircraft during data collection period were created



En Route Domain Application Message Model

Application Message Distribution	Priority (Note 6)	Uplink (From Ground Station)		Downlink (From Aircraft)		
		Average message rate	Average size in bits	Average message rate	Average size in bits	
Exponential inter-arrival with Poisson message size (Point-to-point)	High	0.0076	123	0.0124	92	
	Medium	0.0027	1418	0.0027	73	
	Low	0.001	2400	0.0017	2400	
Constant (Note 4) (Broadcast)	Low	0	0	0.0033	1760	

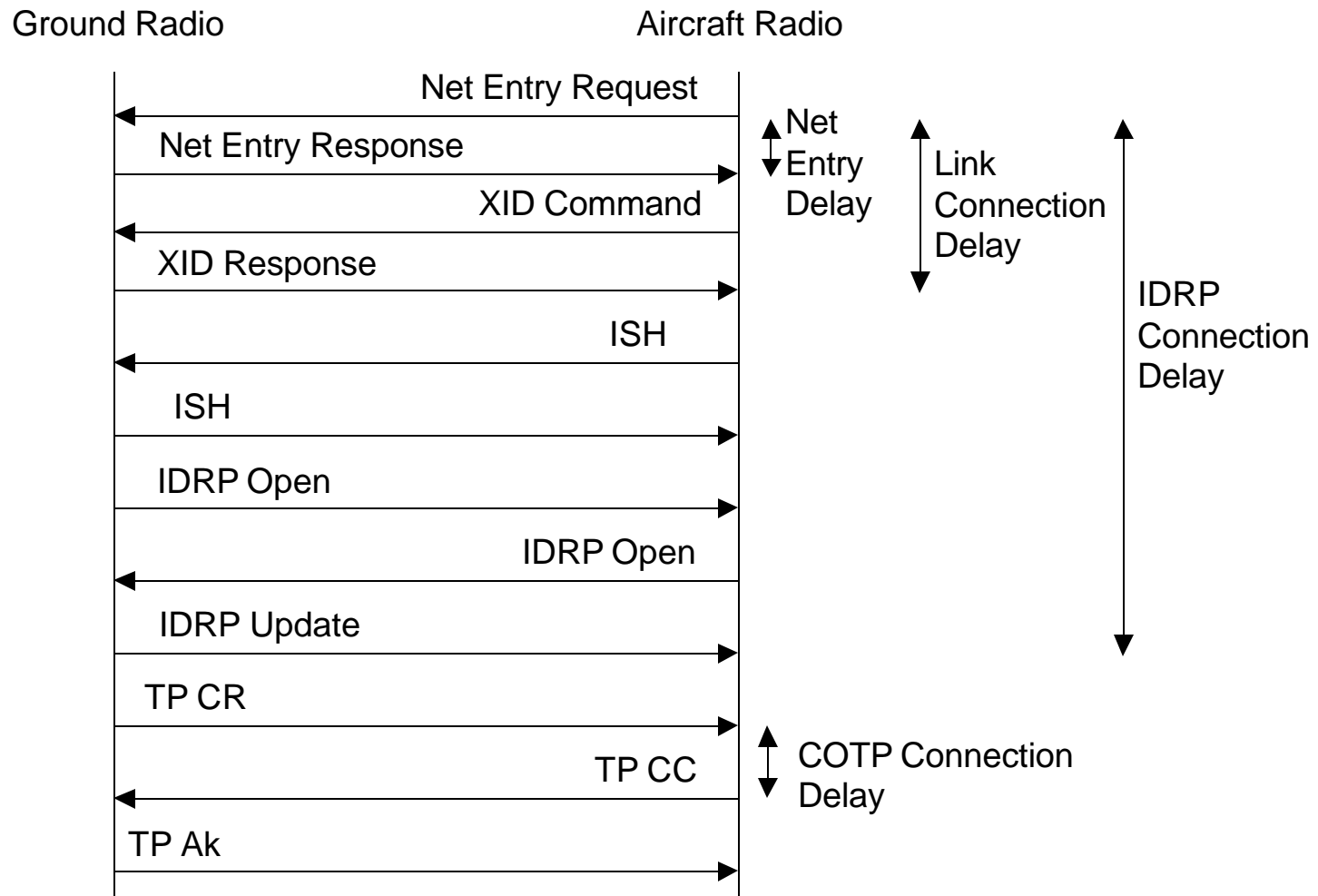
- Notes:
1. Rates are in number of messages per second per aircraft
 2. Each message is acknowledged at the Data Link Sublayer except broadcast
 3. Ack of uplink message uses downlink M Subchannels; ack of downlink message required 4 octets conveyed in the V/D (data) subchannels
 4. Periodic fixed size downlink meteorological observations
 5. All traffic collectively represents a Load Factor of 1
 6. Each priority has its own COTP connection except for broadcast messages

Terminal Domain Application Message Model

Application Message Distribution	Priority (Note 7)	Uplink (From Ground Station)		Downlink (From Aircraft)		
		Average message rate	Average size in bits	Average message rate	Average size in bits	
Exponential inter-arrival with Poisson message size (Point-to-point)	High	0.017	137	0.024	110	
	Medium	0.0017	198	0.0008	100	
	Low	0.001	2400	0.002	2400	
Constant (Notes 4 & 5) (Broadcast)	Low	0.017	3325	0.0033	1760	

- Notes:
1. Rates are in number of messages per second per aircraft
 2. Each message is acknowledged at the Data Link Sublayer except broadcast
 3. Ack of uplink message uses downlink M Subchannels; ack of downlink message required 4 octets conveyed in the V/D (data) subchannels
 4. Uplink broadcast messages are represented by constant uplink messages
 5. Periodic fixed size downlink meteorological observations
 6. All traffic collectively represents a Load Factor of 1
 7. Each priority has its own COTP connection except for broadcast messages

Some Performance Metrics



Summary

- **Presented a summary of some of the aeronautical communications systems modeling and simulation capabilities at MITRE/CAASD**
- **These models have been used in**
 - **system development**
 - **standards development**
 - **system performance evaluation**
 - **system performance improvement**